MATHEMATICAL MODELS FOR HUMAN AND BABOON BRAIN PARAMETERS

By
G.P.Pokhariyal
School of Mathematics, University of Nairobi, Kenya

ABSTRACT – *In this paper linear measurements from ten human and ten baboon brains were used to predict various values for human and baboon brain and body parameters, through multiple regression models. Inter-species values were also predicted through simulation techniques by using the ratios of model parameters with application of programming language Python*.

Introduction

Brains of mammals vary in size and shape, but have similar basic structural organization consisting of cerebrum, cerebellum and brain stem (Bear et al, 2001). The variations in the size of the whole brain, its components as well as their morphology in different species appear to be influenced by the process of functional complexity, evolution and adaptations (Bear et al., 2001,Clark et al, 2001). Adult human brain weighs on average 1.4 kg which is about 2% of the total body weight, while the average adult baboon brain weigh 137 gms, which is nearly 1% of the total body weight (Blinkov and Glezer, 1968). Cerebellum constitutes nearly 13% of the weight of the brain and coordinates body movements, posture and balance. Brain stem is nearly 2% of the weight of the human brain and connects the cerebrum, cerebellum and spinal cord and has vital centres.

The cerebrum has sulci and gyri with lobes having functional localization and constitutes nearly 85% of the weight of a human brain. The cerebral hemispheres are involved in all the voluntary (conscious) activities of the body, intelligence, learning and memory.In the human, the right hemisphere is associated with creativity and artistic ability while the left hemisphere is associated with analytical and mathematical ability. The left hemisphere is more dominant in humans and has relatively higher values of the parameters (Blinkov and Glezer, 1968).

The size and structure of the frontal, parietal, temporal and occipital lobes are associated with the functional complexity of the mammals (Bear et al., 2001). Body size and weight have been associated with size of brain and its components, but this relationship has not been explicitly expressed (Clark et al, 2001, Kass 2000). Comparative analysis of selected linear measurements of cerebrum from lateral, superior and inferior aspects for humans and baboons has been conducted to show morphometric differences(Hassanali et al, 2007).

Through regression models and simulating techniques an attempt can be made to establish a relationship between the brain and body parameters.
Simulation modeling is a process which starts and ends with gaining insight about the systems. The abstraction allows a model to represent complexities of the real world process, device or concept. The structure of the relationship between real and conceptual worlds is basically a part of scientific method which involves data collection, such that investigators get appraisal of the real world, understanding the observations and analyzing the situation.

Models are predictors of future or values that also test the validity and consistency of observation. Simulation models are described by means of mathematical symbols and involve in step by step segmental calculations where the workings of systems or large scale problems can be reproduced. The input data in a simulation model may be real or generated. Multiple regression models predict the values of dependent variable involved with more than one independent variables, Murthy et al. (2000).

The model's two activities, validation and application occur during software development. Model validation involves retrospectively demonstrating that model consistently predicts actual values with acceptable accuracy. The validation of simulation is conducted for the same reason as the rerunning of the actual experiments. The process of validation often assists in gaining the insights which are then used to modify the models. The simulation process changes to reflect the improvement in the understanding of the model. The modeling aspect asks and answers questions about a system using a particular paradigm, while the validation answers the question regarding the accuracy in which models reflect objective observations (Stevenson, 1999).
The present study aims at using the linear measurement of human and baboon brains to predict, through regression models and simulation methods, various values for human and baboon brains and body parameters.

Materials and Methods

Ten human and ten baboon formaline fixed brains obtained from Department of Human Anatomy and Institute of Primate Research respectively were used for the study. Three human and three baboon brains were separated into components of the cerebral hemispheres, cerebellum and brain stem. The components were weighed and mean values for the whole brains and components were obtained The linear measurements taken from the lateral, superior and inferior aspects were analysed in the previous study Hassanali et. al. 2007). For the present study 3 human and 2 baboon brain data was added to the previous sample.

Height of Temporal lobe (HTL): The perpendicular distance from the point (X) where the central sulcus (CS) meets the lateral sulcus(LS) to the inferior margin of the temporal lobe(Y).

Figure 1, 2 and 3 show the linear measurements used for the regression model.

Fig. 1 Lateral aspect: Human Baboon

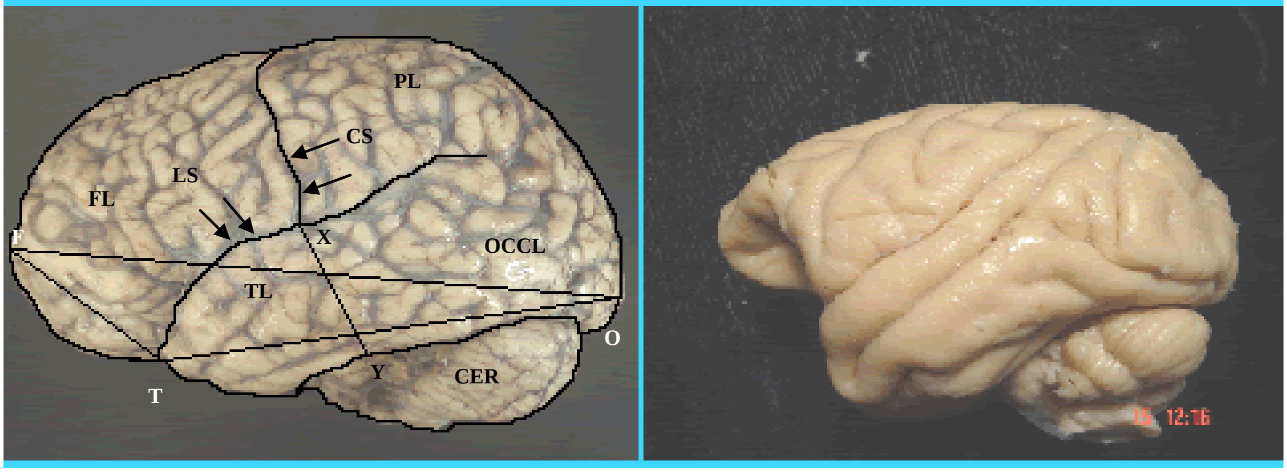


Fig .2 Superior aspect: Human Baboon

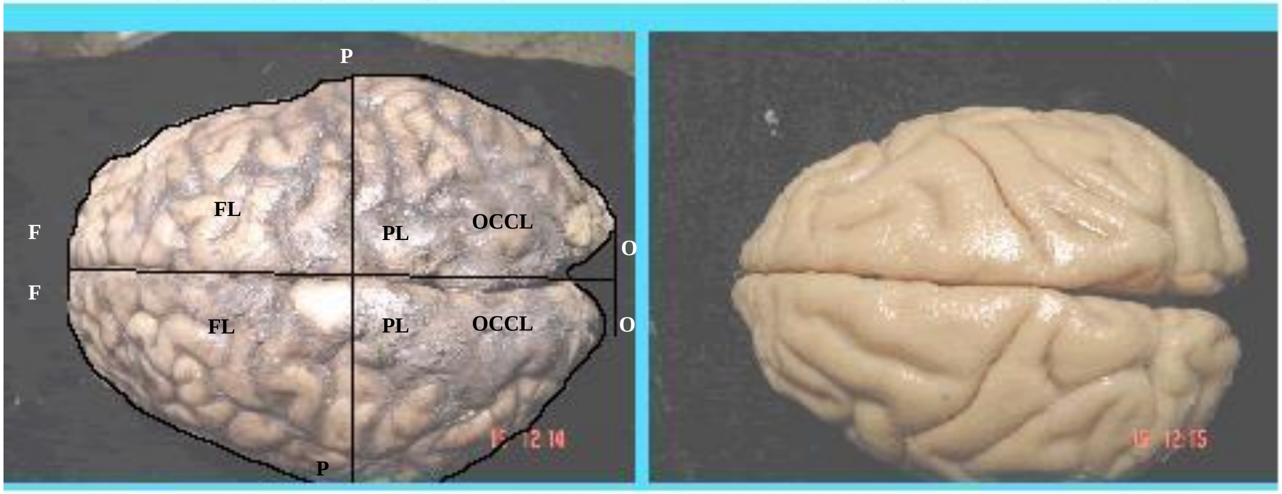
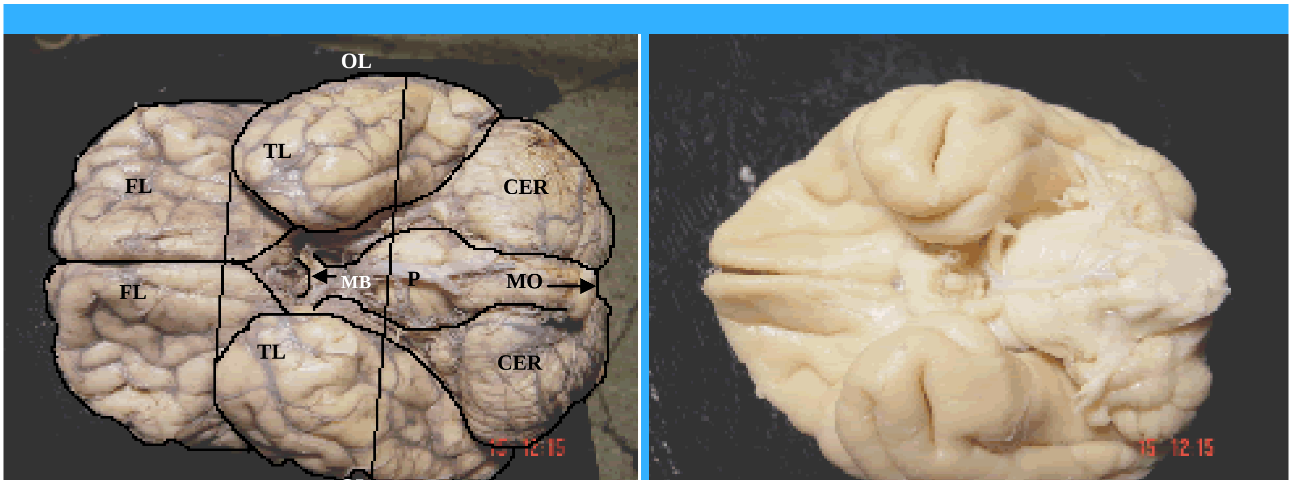


Fig. 3 Inferior aspect: Human Baboon



Inter-Frontal (F-F): The distance between the poles of the frontal lobe
Inter-Parietal (P-P) Maximum distance between the parietal lobes (width)
Inter-Occipital (O-O): The distance between the poles of the occipital lobes.

Inferior Aspect (Fig 3)
Inter-Temporal (T-T): The distance between the right and left temporal lobes.
Inter-Occipital (OL-OL): Maximum distance between occipital lobes.

Modeling Procedure
The need assessment was conducted to determine the simulation and modeling functions that were required by the user from the system. It was found that the users need to:

- View the analytic data in 3-D representation, zoom, rotate features and graphs.
- Determine the existence of relationships between brain parameters.
- Simulate other measurements from the available data.

The corresponding tools were accordingly developed and the context diagrams were then drawn. The collected data was stored in simple text files. Design of interface layouts dealing with structuring data entry, collecting data input, feedback and help were done. Designing the dialogue sequence building a prototype and assessing its usability were accomplished.

Multiple regression model was used to estimate brain weights using OF, FT, OT and HTL as explanatory variables, for both baboon and human subjects. The statistical significance of each of the coefficient of the model parameters was investigated.
Cross species simulations were conducted, using the ratios of the model parameters, for computing the baboon and human values. The programming language Python was used, which is considered compact and extensible. The simulations were conducted using Intel Pentium IV, 1.7 Ghz with 256 MB RAM having hand disk space of 40GB.

Results: The results from the analysis are shown in the following tables:

Regression Human

Descriptive Statistics

	Mean	Std. Deviation	N
BRAIN WEIGHTy	1329.850230414747	37.61378262900072	10
FOX1	17.05	.64	10
FTX2	5.9740	.7938	10
TOX3	13.0520	.4500	10
HTLX4	4.428913	.321785	10

Correlations

		BRAIN WEIGHTy	FOX1	FTX2	TOX3	HTLX4
Pearson Correlation	BRAIN WEIGHTy	1.000	.962	.810	.200	.652
	FOX1	.962	1.000	.878	.252	.663
	FTX2	.810	.878	1.000	.493	.804
	TOX3	.200	.252	.493	1.000	.380
	HTLX4	.652	.663	.804	.380	1.000
Sig. (1-tailed)	BRAIN WEIGHTy	.	.000	.002	.289	.020
	FOX1	.000	.	.000	.241	.018
	FTX2	.002	.000	.	.074	.003
	TOX3	.289	.241	.074	.	.139
	HTLX4	.020	.018	.003	.139	.
N	BRAIN WEIGHTy	10	10	10	10	10
	FOX1	10	10	10	10	10
	FTX2	10	10	10	10	10
	TOX3	10	10	10	10	10
	HTLX4	10	10	10	10	10

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.969[a]	.938	.889	12.5346683392033	.938	19.011	4	5	.003

a. Predictors: (Constant), HTLX4, TOX3, FOX1, FTX2

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11947.580	4	2986.895	19.011	.003[a]
	Residual	785.590	5	157.118		
	Total	12733.170	9			

a. Predictors: (Constant), HTLX4, TOX3, FOX1, FTX2

b. Dependent Variable: BRAIN WEIGHTy

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	95% Confidence Interval for B Lower Bound	Upper Bound
1	(Constant)	203.332	299.962		.678	.528	-567.744	974.408
	FOX1	66.190	15.323	1.128	4.320	.008	26.802	105.578
	FTX2	-14.043	16.556	-.296	-.848	.435	-56.603	28.516
	TOX3	.744	11.904	.009	.063	.953	-29.857	31.345
	HTLX4	16.280	22.185	.139	.734	.496	-40.749	73.308

a. Dependent Variable: BRAIN WEIGHTy

Regression Baboon

Descriptive Statistics

	Mean	Std. Deviation	N
BRAIN WEIGHTy	113.36691584507020	2.89372025708526	10
FOX1	8.493383	.400810	10
FTX2	3.865067	.351346	10
TOX3	6.71680000000000	.31430263586801	10
HTLX4	2.32828333333333	.25382651859727	10

Coefficients

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	51.503	.216		238.110	.000
	FOX1	7.629	.122	1.057	62.752	.000
	FTX2	-.456	.101	-.055	-4.497	.006
	TOX3	-.270	.107	-.029	-2.516	.053
	HTLX4	.277	.063	.024	4.372	.007

a Dependent Variable: BRAIN WEIGHTy

Correlations

		BRAIN WEIGHTy	FOX1	FTX2	TOX3	HTLX4
Pearson Correlation	BRAIN WEIGHTy	1.000	1.000	.754	.780	.334
	FOX1	1.000	1.000	.762	.773	.328
	FTX2	.754	.762	1.000	.277	.493
	TOX3	.780	.773	.277	1.000	.343
	HTLX4	.334	.328	.493	.343	1.000
Sig. (1-tailed)	BRAIN WEIGHTy	.	.000	.006	.004	.173
	FOX1	.000	.	.005	.004	.177
	FTX2	.006	.005	.	.219	.074
	TOX3	.004	.004	.219	.	.166
	HTLX4	.173	.177	.074	.166	.
N	BRAIN WEIGHTy	10	10	10	10	10
	FOX1	10	10	10	10	10
	FTX2	10	10	10	10	10
	TOX3	10	10	10	10	10
	HTLX4	10	10	10	10	10

The average brain weight for baboon was found to be 0.8384% of the body weight, where as the average brain weight for was 3.0769 of the body weight. The mean length (O-F) and width (P-P) of human brain were found to be in the ratio of 1.3077, where as for baboon brain this ratio was 1.25.

Table 1 shows brain weight and the values of OF (x_x), FT (x_2), OT (x_3) and HTL (x_4) for baboon data. The multiple regression equation estimating the brain weight (Y) of baboon was obtained as

$$Y = 7.629x_1 - 0.456x_2 - 0.27x_3 + 0.277x_4 + 51.503 \qquad (3.1)$$

Table 2 shows brain weight for human data. The corresponding multiple regression equation for estimating brain weight of human was obtained as

$$Y = 66.19x_1 - 14.043x_2 + 0.744x_3 + 16.28x_4 + 203.332 \qquad (3.2)$$

It was observed that OF (x_1) and HTL (x_4) contribute positively where as FT (x_2) contributes negatively towards the brain weight for both baboons and humans. The OT (x_3) contributes negatively for baboon and positively for human brain weight. The corresponding elasticity of the explanatory variables was found to be quite high for humans in comparison to baboons. The $t-$statistics showed that for baboon data except OT (x_3) all other variables were significant in estimating the brain weight. Thus, the amended regression using OF (x_1), FT (x_2) and HTL (x_4) was found to be

$$Y = 7.34x_1 - 0.23x_2 + 0.15x_4 + 51.56 \qquad (3.3)$$

Similarly, through t-test for human data only OF (x_1) was formed to be statistically significant. Thus the amended regression was obtained as

$$Y = 56.48x_1 + 366.86 \qquad (3.4)$$

Estimation of brain weight

By using the mean values of the parameters the brain weights for human and baboon were estimated. Using (3.1), the baboon brain weight was found to be

$$\begin{aligned} Y &= 7.629(8.493383) - 0.456(3.865067) - 0.27(6.7168) + 0.277(2.32833) + 51.503 \\ &= 113.3730566 gms \end{aligned} \quad (3.5)$$

Using (3.3) which contains statistically significant parameters, the estimated brain weight for baboon was estimated as:

$$\begin{aligned} Y &= 7.34(8.493383) - 0.23(3.865067) + 0.15(2.328333) + 51.56 \\ &= 113.361758 gms \end{aligned} \quad (3.6)$$

Using (3.2), the human brain weight was found to be

$$\begin{aligned} Y &= 66.19(17.05) - 14.043(5.974) + 0.744(13.O52) + 16.28(4.428913) + 203.332 \\ &= 1329.79201 gms. \end{aligned} \quad (3.7)$$

Similarly using (3.4) which contains statistically significant parameter, the estimated brain weight for human was obtained as:

$$Y = 56.48(17.05) + 366.86 = 1329.844 gms. \quad (3.8)$$

The elasticity of the model parameters revealed that unit percentage increase in OF would increase the baboon brain weight by 7.629% whereas unit percentage increase in HTL would increase the baboon brain weight by only 0.277%. However, the unit percentage increase in OF and HTL would increase the human brain weight by 66.19% and 16.28% respectively. On the other hand, unit percentage increase in FT would decrease the baboon and human brain weights by 0.456% and 14.043% respectively.

Error of estimation

The estimated brain weights of baboon and human obtained through respective regression lines are compared with the mean weights obtained from data vales to compute error of estimation. Using (3.1), the estimation error was found to be 0.0054%, while using (3.3) the estimation error was –0.0046% for baboon brain weight. Using (3.2), the estimation error was found to be –o.oo44%, while using (3.4), the estimation error was –0.0005% for human brain weight.

Simulation Model

The ratios between linear measurements for human and baboon as well as cross species ratios were computed. These ratios were then used to simulate brain weights for human and baboon. The following results were obtained from the simulation models

Human OF = 2.85 human FT = 3.84 human HTL
Human OF = 2.01 baboon OF
Human FT – 1.55 baboon FT
Human HTL = 1.91 baboon HTL

Using baboon OF, the human OF was found to be
Human OF = (8.49) 2.01 = 17.0649

Using the equation 3.4 and above simulated value, the human brain weight was obtained as

Human brain weight = 56.48 (17.0649) + 366.86
= 1330.685552 gm

Discussion

It was noticed that OF (x_1) and HTL (x_4) values contributed positively and the elasticity of these parameters indicated the extent of increases in the baboon and human brain weights. The increase in OF for humans was found to be contributing about 66 times to the increase in the brain weight as compared to nearly 7 times in the baboon case. The increase in HTL contributed only nearly one fourth times for baboon brain weight as compared to nearly 16 times for human brain weight. It was found that FT (x_2) contributed negatively towards the brain weights for both baboon and humans, with a decrease of nearly 14 times for human case in contrast to nearly one fourth times for baboon case . The value OT (x_3) contributed, negatively for baboon brain weight at the rate of nearly one fourth of a percentage, while positively for human brain weight at the rate of nearly three fourth of a percentage. The errors of estimation were found to be almost negligible for all cases, as seen in the results.

These parameters can further be used to estimate the brain weights as well as body weights for human and baboon subjects individually and across species through simulation model

The comparative aspects of the selected linear parameters in the antero-posterior, lateral and inter frontal, temporal and occipital planes reflects on the enlargements of the lobes and functional areas of the cerebrum (Kass, 2000)

The frontal lobes in the humans have enlarged proportional to the parietal, temporal and occipital lobes (F-F, FT). The frontal lobes with high cognitive functions is associated with complex connections (OF) has to positive contribution in the modeling.

The parietal lobes are central for orientation, object identification, recognition and conscious perception as well as motor and sensory functions (P-P).

The temporal and occipital lobes as are also involved in the final visual cortex for object recognition such that one recognizes face and facial emotions**.**

Compared to the baboons, humans have the speech (HTL) and visual cortex with functional complexity of associated visual cortex (OL) inter occipital (O-O) and (T-T). The evolutionary trends in brain size and weights in primates and hominids have shown relative changes in cortical functional areas reflecting on the selected linear parameters considered in the regression model.

In conclusion it can be said that the model can be tested using parameters of other non-human primates to estimate brain weight, body weight and height. It can be useful in estimating parameters of hominids and humans from brain or endocasts.

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